α, which is smaller than the critical angle for the total reflection in the continuous optical waveguide. The continuous optical waveguide has a diameter of 50 to 6000 µm.

US 6,553,164 shows a waveguide-based Y-coupler, which is composed of 4 individual sub-elements.

DE 694 14 139 T2 describes a coupling arrangement between a multi-mode light source and an optical fiber by means of an intermediate fiber, which is designed as an optical multi-mode intermediate fiber. The intermediate fiber comprises a sub-region having a cross-section and a tapering sub-region. A Y-coupler is designed by means of the tapering intermediate fiber.

US 2004/0072358 A1 describes a glucose detection device, which comprises a sensor, a light source and a photodetector, which are connected to one another by an optical fiber. Furthermore, a Y-coupler is utilized, which is formed by an optical fiber splitting into two strands.

Proceeding from US 2004-0072358 A1, it is an object of the present invention to provide an improved arrangement for operating a biosensor. The arrangement is intended both to supply the excitation radiation and to be able to detect the measurement signals generated by the sensor with high sensitivity. In the process, a small, integratable design, a secure mechanical connection to the biosensor and high optical reliability are to be achieved. In addition, it is considered to be an object to provide an improved arrangement for determining the glucose content, in particular in blood, which allows a mobile, quasi-continuous measurement of the glucose content.

Summary

These and other objects are achieved by an arrangement for operating a biosensor according to an aspect.

According to the aspect, the present disclosure refers to an arrangement for operating a biosensor emitting radiation, comprising:

- an excitation light source, which generates at least one excitation radiation for the biosensor;
- a coupling fiber, at the entry surface of which the excitation radiation is coupled in;
- an optical detector; and
- an optical Y-coupler, including an excitation arm, which is connected to the exit surface of the coupling fiber, a detector arm, which is connected to the optical detector, and a sensor foot, which can be connected to the biosensor,

wherein the excitation arm has a conical shape, wherein the radiation axis of the excitation arm includes an angle in the range of 5° to 70° with the main radiation axis of the detector arm at a connecting point between the detector arm and the excitation arm, wherein the diameter of the excitation arm at the connecting point to the detector arm being less than two thirds the diameter of the detector arm, and wherein the excitation arm has a cross section tapering in the direction of the radiation.

The arrangement according to an example for operating a biosensor includes an excitation light source, which generates at least one excitation radiation for the biosensor. The arrangement furthermore comprises a coupling fiber, at the entry surface of which the excitation radiation is coupled in. In addition, an optical Y-coupler is provided, which includes an excitation arm, which is connected to the exit surface of the coupling fiber, a detector arm, which is connected to an optical detector, and a sensor foot, which can be connected to the biosensor. The detector arm and the sensor foot preferably have a shared main radiation axis. The radiation axis of the

excitation arm extends at an angle in the range of 5° to 70°, preferably 5° to 30°, with respect to the main radiation axis of the detector arm. The excitation arm has an elongated, conical shape, wherein the diameter of the excitation arm, at the entry point into the detector arm, is less than two thirds the diameter of the detector arm at this connecting point, preferably less than half, and particularly preferably less than one third of the diameter of the detector arm.

The excitation light source is preferably formed by an LED chip, which emits excitation radiation of 595 nm, for example. The excitation radiation is adapted to the biosensor in terms of the wavelength and optical power and can, for example, also contain two wavelengths if this is desired for the particular application purpose. The emission plane of the LED chip is preferably positioned at a distance of 0.1 to 10 times the diameter of the coupling fiber from the entry surface of the coupling fiber.

According to a preferred example, the excitation light source is a planar, diffusely emitting emitter. The emission is preferably carried out from a thin layer, as is the case, for example, with a thin-film LED. The excitation light source is thus particularly preferably formed by a thin-film LED.

The coupling fiber is preferably a PMMA fiber or a sapphire fiber, which has a spherical, aspherical or planar entry surface, for example, which is located opposite the excitation light source. The coupling fiber preferably has a diameter that is constant across the length thereof and that is in the range of 0.1 to 2 mm, more preferably 0.3 to 0.7 mm, particularly preferably 0.5 mm, and a length that is preferably 7 times to 13 times the distance between the excitation light source and the entry surface of the coupling fiber, for example 5 to 15 mm, particularly preferably 10 mm. The entry surface of the coupling fiber is preferably spaced approximately 0.8 to 1.2 mm, particularly preferably approximately 1 mm, apart from the excitation light source, wherein the excitation beam preferably extends in air at this distance. This distance causes only "flat beams" to be coupled into the coupling fiber, which thus have only a small angle with respect to the central axis of the coupling fiber. The emitting surface of the excitation light source preferably corresponds to 10 to 60% of the cross-sectional surface of the coupling fiber.

An advantageous example is characterized in that the coupling fiber does not have a curvature in the axial longitudinal direction, i.e., the longitudinal axis thereof extends rectilinearly. For example, the coupling fiber can be made of a rigid material for this purpose, or may be guided in a non-curved sleeve.

According to a preferred example, the exit surface of the coupling fiber is coupled to the excitation arm of the optical Y-coupler by means of an interposed cut-off filter. As a result of this filter, the wavelengths that correspond to the fluorescence wavelengths emitted by the biosensor can be filtered out of the excitation radiation, so that these can be detected more easily at the detector as measurement signals. The cut-off filter is formed, for example, as a carrier glass

including filter layers applied thereon. The exit surface of the coupling fiber can be glued to this carrier glass, wherein gluing directly onto the filter layers is also possible.

A particularly preferred example is characterized by a specially adapted beam guidance, which allows optimized use of the available optical power. For this purpose, the aforementioned "flat beams" are coupled into the coupling fiber mentioned. "Flat beams" shall be understood to mean beams having a small angular deviation in the direction of propagation. The use of such beams above all allows the cut-off filter to be used efficiently, which already cuts certain wavelengths out of the excitation radiation, which then no longer distort the measurement result. The excitation radiation shall be sought to impinge as perpendicularly as possible on the surface of the cut-off filter, which is achieved when the excitation radiation propagates in the coupling fiber at the smallest possible angular deviation from the longitudinal axis of the coupling fiber, and thus impinges on the cut-off filter at the smallest possible angular deviation with respect to the surface perpendicular of the cut-off filter. The excitation radiation preferably extends in the coupling fiber at an angle of <40° with respect to the surface perpendicular of the cut-off filter or with respect to the core axis of the coupling fiber, particularly preferably at an angle of <30°, in particular <25°.

An advantageous example of the arrangement is characterized in that the diameter of the excitation arm continuously decreases from the entry surface thereof, which is optically coupled to the exit surface of the coupling fiber, in the direction of the point at which it is connected to the detector arm (so-called tapered fiber). The excitation arm thus has the shape of an elongated frustum. At the connecting point, that is, at the position at which the excitation arm, the detector arm and the sensor foot of the Y-coupler converge, the diameter of the coupling arm is thus considerably smaller than at the entry

surface thereof. The diameter of the excitation arm preferably decreases along the longitudinal extension thereof by more than half. In particular, the excitation arm has a diameter in the range of 0.1 to 0.2 mm at the point at which it connects to the detector arm. The tapering of the excitation arm serves primarily the formation of an optical valve, which allows the excitation radiation to be coupled into the sensor foot, while minimizing fluorescent radiation returned from the biosensor from undesirably exiting into the excitation arm.

According to a preferred example, a colored glass piece, which enhances the filter action of the cut-off filter, is located between the coated carrier glass, which adjoins the exit surface of the coupling fiber, and the entry surface of the excitation arm. The colored glass piece is designed in the manner of a waveguide and can likewise have a conical shape. A colored glass piece is a colored, optical filter glass, such as is offered, for example, by Schott AG.

The Y-coupler is preferably made of plastic, and in particular PMMA or PC. For example, 3D printing methods or injection molding methods are suitable for this purpose. The diameters of the detector arm and of the sensor foot are preferably constant, for example in the range of 0.4 to 0.6 mm, and in particular 0.5 mm. The sensor foot can advantageously have a curvature having an angle of approximately 90° in the longitudinal direction, so as to be easily connectable at the exit surface thereof to the biosensor if the biosensor was implanted into the tissue substantially perpendicularly to a patient's skin surface.

An expedient example includes a further colored glass piece in waveguide form, which is arranged between the detector and the exit surface of the detector arm. This colored glass piece, in turn, fulfills filter-enhancing functions. Furthermore, it is advantageous when a lens and a filter are arranged upstream from the detector so as to collimate the fluorescent radiation coming

from the detector arm, and possibly filter out excitation radiation that is still present.

The detector can preferably be designed as a photodiode or as a similar component. If multiple fluorescence wavelengths are to be detected, it may be advantageous to combine a beam splitter with multiple photodetectors of varying sensitivities.

According to the present disclosure, the sensor foot is not only used for the mechanical coupling to the sensor fiber, but also for the beam deflection. Preferably, a toric surface is formed in the sensor foot for this purpose.

An arrangement according to the present disclosure for determining the glucose content, in particular of blood, comprises a biosensor as well as an arrangement for operating the same according to one of the examples described here.

Further advantages and details of the invention will be apparent from the following description of preferred embodiments with reference to the drawings. In the drawings:

FIG. 1 shows a schematic diagram of a first embodiment of an arrangement according to the invention for operating a biosensor;

FIG. 2 shows a schematic diagram of a second embodiment of the arrangement for operating the biosensor; and

FIG. 3 shows an optical beam path in a sensor foot for beam deflection and for coupling into or outcoupling from the sensor fiber, with low optical losses.

FIG. 1 shows an arrangement for operating a biosensor in a simplified lateral illustration. The biosensor is formed as a

Claims

1. An arrangement for operating a biosensor (01) emitting radiation, comprising:
   - an excitation light source (03), which generates at least one excitation radiation for the biosensor;
   - a coupling fiber (04), at the entry surface of which the excitation radiation is coupled in;
   - an optical detector (21); and
   - an optical Y-coupler (12), including an excitation arm (11), which is connected to the exit surface of the coupling fiber (04), a detector arm (13), which is connected to the optical detector (21), and a sensor foot (14), which can be connected to the biosensor (01),

   wherein the excitation arm (11) has a conical shape, wherein the radiation axis of the excitation arm (11) includes an angle in the range of 5° to 70° with the main radiation axis of the detector arm (13) at a connecting point (16) between the detector arm (13) and the excitation arm (11), wherein the diameter of the excitation arm (11) at the connecting point (16) to the detector arm (13) being less than two thirds the diameter of the detector arm (13), and wherein the excitation arm (11) has a cross section tapering in the direction of the radiation.

2. The arrangement according to claim 1, characterized in that the diameter of the excitation arm (11) at the connecting point (16) is less than half as large as at the entry surface thereof.

3. The arrangement according to claim 1 or 2, characterized in that the detector arm (13) and the sensor foot (14) have a shared main radiation axis.

4. The arrangement according to any one of claims 1 to 3, characterized in that the excitation light source is an LED chip (03), the emission plane of which is positioned at a distance of 0.1 to 10 times the diameter of the coupling fiber from the entry surface of the coupling fiber (04).

5. The arrangement according to claim 4, characterized in that the coupling fiber (04) has a length that is 7 times to 13 times the distance between the excitation light source (03) and the entry surface of the coupling fiber (04), in particular in the range of 7 to 13 mm.

6. The arrangement according to claim 4, characterized in that the entry surface of the coupling fiber (04) is designed as a planar, spherical, aspherical or free-form surface.

7. The arrangement according to any one of claims 1 to 6, characterized in that a cut-off filter (07, 08), which filters the wavelength of the radiation emittable by the biosensor (01) out of the excitation radiation, is arranged between the exit surface of the coupling fiber (04) and the entry surface of the excitation arm (11).

8. The arrangement according to any one of claims 1 to 7, characterized in that the coupling fiber (04) is designed with a rectilinearly extending longitudinal axis.

9. The arrangement according to claim 7 or according to claim 8 referenced back to claim 7, characterized in that the cut-off filter is composed of a carrier glass (07) including optical filter layers (08) applied thereon, the exit surface of the coupling fiber (04) preferably being glued to the filter layers (08).

10. The arrangement according to any one of claims 1 to 9, characterized in that a lens (18) is arranged between the exit surface of the detector arm (13) and the detector (21) for collimating the radiation emitted by the biosensor, wherein an optical filter (19), which blocks incoming fractions of the excitation radiation, is arranged between the lens (18) and the detector (21).

11. The arrangement according to any one of claims 1 to 10, characterized in that a colored glass piece (17) in waveguide form is arranged at the exit-side end of the detector arm (13).

12. The arrangement according to any one of claims 1 to 11, characterized in that the sensor foot (14) comprises a curved section, in which a beam deflection is carried out at an angle of more than 45°, and preferably of approximately 90°.

13. The arrangement according to claim 12, characterized in that a beam-deflecting, toric surface (24) is formed in the sensor foot (14).

14. The arrangement according to any one of claims 1 to 13, characterized in that it is designed for determining the glucose content, in particular of blood, and comprising the biosensor (01, 02), which is implantable into tissue and emits a radiation upon excitation.

15. The arrangement according to claim 14, characterized in that the biosensor is formed as an optical fiber (01), which includes glucose-sensitive fluorescent luminophores (02) at the exit surface thereof, which upon excitation by the excitation radiation emit fluorescent radiation having a fluorescent wavelength.